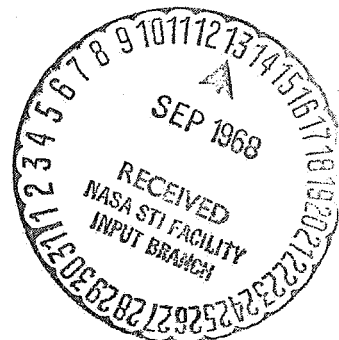


FINAL REPORT

O S O HEAD
AND
TAPE STUDIES

raymond

ENGINEERING LABORATORY, INC.



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RAYMOND ENGINEERING INC.
Middletown, Connecticut

NASA/GSFC
Contract No. NAS5-9395

Raymond W.O. 1031

FINAL REPORT NO. 705-8

O S O HEAD
AND
TAPE STUDIES

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FINAL REPORT

OSO HEAD AND TAPE STUDIES

ABSTRACT

The referenced contract was established as a means by which current recording tape and record-reproduce head problems could be studied. Work being performed on other NASA/GSFC contracts was being held up due to difficulties concerning head/tape characteristics. The problems were severe enough to prevent delivery of much needed flight recorder/reproducers to GSFC.

Under the referenced contract certain types of recording tape were studied relative to the characteristics of the then used magnetic read-write heads. Further efforts were expended in attempting to establish detailed specifications in order to more accurately describe and control key characteristics of procured heads. Basic test plans were written by Raymond to provide test descriptions. Work performed in studying the tape-head problems resulted in solving the present difficulties so that hardware could be made available to GSFC. As a result of the study, the head vendor was changed and a different type of recording tape was used.

GSFC and Raymond Engineering discussions revealed some interesting operational facts associated with the Model 1974 recorder/reproducer.

At the request of GSFC, Raymond made available a list of changes to be made to the basic recorder which would give GSFC greater ease of operation and to some extent improve overall reliability.

A new Statement of Work was written and work began on efforts therein. In brief the areas of endeavor were centered around tape and heads, tape transport operation and electronic system operation. The contract as modified at that time became a very large study program aimed at investigating varied areas of the entire recorder/reproducer system. Throughout the expansion of scope of work, appropriate reviews and increases of funding became necessary. The outcome of the modified contract was the establishment of tape life tests to determine specific tape characteristics. GSFC provided excellent support during life testing, particularly in the analysis, both physical and chemical, of tape operated in life test systems. Review of test data from tape studies showed that certain tapes would not be suitable for use in the OSO recorders and that only one head vendor could be trusted to provide a head built to specific program needs.

Work performed in the area of the electronics portion of the recorder system brought about the use of improved semiconductors and the incorporation of additional features, such as a D.C. erase capability. The study program recommendations were referred to GSFC for possible incorporation in an in-process flight hardware program.

A review of the recorder from a system point of view revealed some improvements could be made to the wiring and cabling so as to provide

better signal to noise ratios. Not all of these recommendations could be incorporated at that time since program continuity would have been impaired. Much of the work performed during this period indicated the need for a program to study recorder components and characteristics in greater detail. NASA recognition of this fact resulted in a further increase of scope aimed at providing data by which future recorder evaluation could be more accurately realized.

The final contract modification provided funds for additional life tests under accelerated life conditions and the re-writing of pertinent hardware test procedures. The need was recognized that the inclusion of more detailed procedures, test plans and inspection techniques would provide GSFC a more sophisticated product whose overall identity and characteristics could be recognized and predicted. The spin off benefits of this study program have been incorporated into hardware build programs so as to provide the improved product needed by GSFC in its modern spacecraft programs.

GENERAL

The subject contract was awarded Raymond Engineering to provide a means for the study of critical recording tape and magnetic head characteristics. The need for such a program arose out of difficulties experienced during the hardware phase of the OSO D and OSO E programs. Tape and head difficulties appeared which caused schedule situations deemed untenable by GSFC and which required immediate resolution.

1.0 PROGRAM ON ORIGINAL CONTRACT

Contract No. NAS5-9395 issued September 28, 1966 provided funding to establish means for the identification of parameters which alone or in combination would cause the mal-performance currently being experienced.

Subsequent investigation of the tape and heads provided knowledge that the present tape, 3M #LR1220 was not capable of providing adequate oxide and lube stability. Further investigation led to the conclusion that the read-write heads suffered from inability to perform over temperature. These heads originally procured from IMI, Glendale, California, were no longer suitable. Thus the primary goal was the selection of improved heads and tape. Specifically, the following approach was used to determine the areas of interest.

1.1 Original Head-Tape Study Program.

The basic problem with the recorder was an excessive build-up of tape debris. Analysis of debris samples indicated composition was roughly half oxide and half lubrication, the lubrication being graphite powder. However a further complication seemed to be cropping up. Some evidence of tape to head adhesion appeared. Attempts to correct for poor tape stability would have been futile without first establishing and isolating head oriented problems.

Analysis of the record-playback head in the classical sense was not possible since the head is a very complicated conglomeration of plastics and metals. The route chosen was one which has served Raymond well in similar instances. A comprehensive series of temperature tests were performed on the IMI heads. The heads exhibited core shift, gap misalignment and weepage of liquid material from the core area. IMI was contacted and asked to provide information and help towards solving the problem. As time was critical, the need for a rapid solution was quite visible. Review of IMI techniques and test methods revealed an inability to provide Raymond with heads of the quality level needed on a program such as OSO. Therefore head procurement specifications were reviewed and revised with the hope of building into the specifications sufficient testing safeguards to prevent further difficulty. At the same time discussion began with the Applied Magnetics Company of Goleta, California, a high quality magnetic head manufacturer with an excellent record of performance. The revised head specifications were forwarded to AMC for quote and technical review. AMC indicated to Raymond that heads identical to those manufactured by IMI would not be available but a similar device could be supplied. The basic parameter which would be different was in the area of winding inductance.

A purchase order for flight heads was then let to AMC. The heads were tested to revised head test procedures both at AMC and Raymond. Performance was found to be satisfactory but some core shift and lamination displacement still occurred. AMC was again consulted and an approach to eliminate the problem through temperature cycling was evolved. Special test fixtures were designed and built by Raymond to control and evaluate heat testing. Heads procured by the updated procurement specification and then tested to the new procedures yielded a head capable of the performance criteria established as necessary to the success of the OSO program. Documents generated on this portion of the study program were later incorporated into the flight program as permanent control documentation.

A parallel effort during the head investigation concerned tape stability analysis. The recording tape originally used in the OSO series of recorders was Minnesota Mining and Manufacturing (3M) type LRL220. This was a lubricated instrumentation tape considered at the time as well suited for use in endless loop recorder configurations. It had been proven both by industry and NASA that the LRL220 configuration exhibited reasonable life characteristics. Evidence of tape failure after only a few tape cycles was noted during recorder bench testing during the OSO D

program. The tape breakdown was attributed to many things including head damage but analysis of recovered debris and examination of tape revealed a basic change in tape characteristics. It was apparent from visual examination of the tape that 3M had drastically changed the method of applying the lubrication coating to the backside of the tape. The original LR1220 had been uniformly coated with lubricant whereas the tape now in use had a "diamond" appearance consisting of discrete deposits of lubrication along the tape surface. The tape was returned to 3M with complaints concerning its lack of performance. 3M in due time informed Raymond that it had changed over to a gravure process of coating and would no longer make available the original 1220 structure. Raymond correspondence with 3M during this period stressed the fact that 3M acted in poor harmony with industry in general since a gross product change occurred without benefit of identification. 3M later re-identified the tape as MT22049. As it turned out this 22049 tape was 3M's replacement for 1220 which was no longer available.

Since all hardware built to date employed LR1220 tape, it was necessary to investigate the characteristics of the new tape and try to establish whether 22049 could be used with any degree of confidence. It was also necessary for Raymond to become involved with 3M more than would have been desired

under other circumstances. Raymond personnel traveled to 3M for a series of conferences to try to exact data which would lead to successful use of the tape. 3M could not provide specific data on the characteristics of the tape. It was essentially Raymond's job, at this juncture, to do whatever could be done to make use of the modified tape.

A study program aimed at allowing use of the tape through simple recorder adjustment yielded reasonable results for a short period of time. However 3M either made further changes to its product or lost control and tape instability again became a problem. Raymond at the request of NASA began an accelerated tape study program aimed at reaching a final solution. The study was primarily concerned with tape but recorder modifications which would allow wider tape variations were also considered.

Many different tapes were tried with little success during the study program. Fortunately 3M had introduced type 8998 lubricated tape at just about the time the study program began. This 8998 tape proved to be an improvement over MT22049 since it exhibited far better life and stability characteristics. Having no other recourse, a commitment to the use of 8998 was made and in process hardware was fitted with this tape. Testing of the tape was time limited to performance criteria in transports of the

same configuration as those destined for flight. Under these less than desirable time limited conditions, reasonable confidence was gained in the ability of 8998 to perform.

At the request of NASA, Raymond undertook a program to write tape procurement specifications and tape handling procedures. This task later proved to be of limited value since 3M was in production of 8998 for the consumer market, chiefly stereo cartridges, and did not consider involvement in space exploration technology as particularly rewarding. The documents generated during the initial phases of the study program were later revised and now are part of normal program documentation. All documents were reviewed by GSFC prior to use.

1.2 Revised Study Program - Tape, Heads, Semiconductors

The efforts outlined in section 1.1 of this report constituted the short term approach to successful culmination of a serious problem. However, much knowledge was gained concerning the vagaries of tape and the mutual feeling of GSFC and Raymond was to become more involved so as to prevent recurrence of the problem. Therefore a modification to the contract was incorporated by GSFC directing Raymond to further investigate tape and its effects on specific recorder characteristics. The study was, however, not to be limited to the above and would

include a look at areas within the recorder which could be improved with the aim of greater reliability and confidence.

A series of meetings between GSFC and Raymond personnel were held to go over the entire recorder system and determine the areas of interest which would best bring about direct improvement. In some instances consideration of technology advances made during the OSO program were of benefit since the recorder used semiconductors no longer considered to be ideal for the task at hand. Therefore Raymond examined the possibility of replacing Mesa devices such as 2N722 and 2N1132 transistors with more modern planar passivated types. Leakage characteristics of the original devices were studied along with the effect of leakage currents upon recorder performance. Mesa devices were used in a number of areas within the recorder electronics system which were quite critical to performance. Raymond made contact with semiconductor manufacturers and gained history on device performance. Simulation of actual circuits at Raymond indicated that all Mesa devices should be replaced by newer planar types. This change was made a part of the program documentation.

Another area of concern was the device used in the output stages of the two motor drive amplifiers. The 2N2034

device used in earlier models was adequate but a newer Fairchild device was studied as a possible replacement. The 2N2890 Fairchild transistor was ultimately selected as a replacement for the 2N2034. A breadboard study backed up a preliminary paper study proving the Fairchild device's suitability. The change was incorporated into all new programs.

In order to more fully understand the behavior of recording tape in actual use, GSFC requested further studies be performed. The second series of tape tests were aimed at identifying more esoteric characteristics which could be responsible for the occasional failure of a given length of tape. At this time the National Bureau of Standards was brought into the picture by GSFC. NBS was to physically and chemically study samples of tape operated in recorders of OSO configuration. Surface characteristics such as texture, coefficients of friction, wear rate and stiffness would be examined. The hope was that one or more key parameters would be isolated. The isolated parameters would then be studied in order to gain knowledge in the control and use of the tape. Raymond equipped recorders with both 1220 and 8998 tape for this series of tests and ran the units for periods ranging up to 2000 hours at orbital and P/B modes. Simultaneously, data was to be gathered concerning wear and life patterns of

the newly acquired AMC read-write heads. The data from this head study would be valuable in determining overall AMC performance.

Other investigations during this period involved the examination of head azimuth shift. The test established a practical means of determining the degree of sensitivity to tape skew. The tests were performed with full track and half track head configurations. Test results indicated less effect from skew would occur using half track heads but the reduced output of such a head precluded its use in the system.

The outcome of the tape testing outlined above was inconclusive. The NBS studies revealed some interesting facts concerning lubrication adhesion, wear patterns, degree of lubrication (quantity) and electrical conductivity. However, no direct change in philosophy towards tape resulted from the study. The only thing in the way of a useful approach resulted from the fact that of three procured batches of tape, one batch was considered better for use in the recorder. Apparently the correct amount of lubrication happened to be on that lot. Parameters to verify or establish correlation between performance and physical characteristics remain mysteriously hidden.

Tests results in early OSO configuration recorders proved

that 2000 hour operation in orbital mode was feasible. Tape such as LRL220 compared reasonably well to 8998 under these conditions. The tests were misleading however because the sample rate was so low.

1.3 Revised Study Program - Electronics

The OSO recorder electronic system had been modified a few times as technology improvements warranted and program time permitted. A good example was the decision to eliminate the use of P/B signal level detection and employ an improved peak detection system. GSFC and Raymond examined the present recorder system from the point of view that improvements could be made in areas which had not been evident during earlier programs.

The tape recorder requires a stable clock input from the spacecraft. This clock signal is counted down by recorder circuitry and applied to the motor drive amplifiers as the primary signal which is supplied to the synchronous record and playback motors.

This approach is not unusual since many spacecraft recorders function in this manner. However, the basic design of the recorder motor drive system is such that loss of the spacecraft clock could seriously damage components of the motor drive. This problem had been realized many times but was not considered an operational situation.

The concern was that clock signals never be removed during bench testing. Therefore precautions were taken to carefully control test procedures so that inadvertent loss of clock would not occur. This was done well enough so that no known recorder damage ever occurred.

Later knowledge of spacecraft operation revealed that there were situations in which the spacecraft clock could be interrupted for periods of time, though only milliseconds in duration. Raymond studied the recorder circuitry at length including single and cumulative effects upon components subjected to the stress conditions of brief and lengthy loss of clock conditions. The general problem was that absence of clock caused heavy primary DC current flow through the motor driver-output power switching coupling transformer. Failure could appear as destroyed 2N722 primary driver transistors, motor regulator pass transistor or both. Many approaches to the solution of the problem were set forth by GSFC and Raymond. Test data submitted to GSFC indicated that the basic circuit was sound for normal operating conditions. It was also proven that no easily incorporated change could be made to the present circuit. Therefore no modification was made to the recorder at this time. The approach was to be one involving protective circuits in the spacecraft capable of turning off power if clock signal were

lost. Raymond involvement in the problem was thus limited, at that time, to pointing out the facts surrounding the basic problem.

Other areas of the recorder electronic system were reviewed on this contract. A noise improvement study aimed at reducing internal system noise indicated improved recorder operation could be gained through better signal lead shielding, power decoupling and routing of signal grounds. Recommendations for these improvements were routed to GSFC. These improvements were slated for use on future programs. The benefits of such improvements were laboratory tested at GSFC request.

A study to determine the feasibility of incorporating a DC erase function was performed by Raymond at GSFC request. The need for erasing signal after playback had been apparent for some time but record current limitations of earlier units brought the need to light at this time. Tests were performed using a breadboard system built specifically for this contract study program. The test data revealed the need for an increase of record current. Circuit changes required to provide erase during playback were established. Recommendations were made to GSFC and a plan to incorporate the DC erase feature in new units was established.

1.4 Revised Study Program - Mechanical

Analysis of results from the various tape study efforts outlined resulted in discussion between GSFC and Raymond relative to tape transport modifications. Raymond had expressed a desire to work towards improvement of the recorder consistent with GSFC needs. The discussions led to study of a GSFC designed tape reel configuration which was thought to have merit, particularly in its ability to gently handle tape. Since tape life limitations were of great interest any improvement in tape handling was immediately investigated. Claims were expressed concerning the gentle tape handling of the GSFC reel design, resulting in less force required to pull the tape out of the reel. Raymond agreed to investigate this reel from the point of view that incorporation of the reel into the existing hardware would be feasible.

A series of tests followed manufacture of a quantity of reel models. All fabrication was from GSFC supplied dimensions. The basic reel configuration seemed to be an improvement over the existing reel.

Problems were encountered with the determination of correct reel height and tilt angle. The tilt angle of the endless loop reel configuration is a very critical and complex quantity. An incorrectly positioned reel can cause irreparable tape damage despite any inherent gentleness.

Such were the problems in establishing characteristics of the new design. The reel tilt data was gathered and an adjustable reel mounting base designed. Tests performed indicated no reason not to use this reel. Therefore all future recorders were to be equipped with the GSFC reel configuration.

A GSFC tape guide design was also investigated. This guide is essentially a chute type employing a tapered guide slot. The guide was tried in a test transport using the GSFC reel. Performance was poor due to the lengthy tape-guide contact surface. This guide was not to be used in future hardware.

Early OSO recorders used rubber rollers to force the recording tape against the capstans. Raymond had experience using Mylar belts for this function and suggested use of the belts in new recorders. The rubber roller approach was prone to limited non-operating storage since the roller developed dents at the roller-capstan interface. Belts eliminated this problem. Tests were performed with belts and early failures due to Mylar fatigue developed. Evaluation of the failures resulted in a change of belt thickness. The reduced thickness in pressure belts provided life greatly in excess of 114,000 hours. Life is more than adequate and advantages gained

in simplicity of operation make the choice of pressure belts a good one. Recorders in the future will be equipped with pressure belts.

1.5 Revised Study Program - Documentation

Review of existing recorder test plans revealed shortcomings existed in various areas, but generally a lack of test parameter limits provided the most obvious fault. Raymond studied the history of the recorder test programs and supplied GSFC with recommendations on improving test procedures and equipment. GSFC also requested additional procedures particularly subassembly test plans. Raymond revised existing procedures where applicable and generated new documentation where needed. A recorder handling procedure was written so that the general handling limitations of such equipment would be properly known. A tape transport subassembly procedure and test plan was also written, covering basic subjects such as tape handling and adjustment. The documents were forwarded to GSFC for approval and incorporation into existing hardware programs.

1.6 Final Tape Test Program

As experience was gained in certain recorder operating characteristics, the need for in-depth testing became known. Meetings between GSFC and Raymond resulted in the decision to perform as many life tests as time and

equipment would allow, consistent with current funding. The subject of life tests and test evaluation is a very complex one. Conclusions can only be drawn after basic trends have been established. Therefore, the last section of this report will be a summary of those tests performed at the end of the subject study contract. Existing reports are included in appropriate sections to further expand on reasoning prevalent during the test program.

LIFE TEST SUMMARY

The life tests, a total of eight on this program, can only be used to assist in identifying the major variables in tape life. The tests in themselves cannot be considered conclusive and can only be considered as identifying possible trends in tape life performance in a Raymond Model 1987 Recorder/Reproducer.

Of the eight tests performed, four were in the launch position and four were in the orbital position. Of the four tests in the launch position, one was in laboratory environment, two were in 100% nitrogen environment and one was in 70% nitrogen, 20% Freon, 10% helium. All tests in the launch position were conducted in the S/N 802 machine. The tests conducted in the orbital position were all in 70% nitrogen, 20% Freon, 10% helium environment. Two of the orbital position tests were conducted in S/N 802 machine and two in S/N 801,

one of which was with MT22760 tape and one with 8998 tape. All tests were conducted in continuous P/B (10.8 ips) operation.

Tests in the launch position failed between 3000 and 4000 tape passes. Tests in the orbital position failed between 10,000 to in excess of 16,000 tape passes. The tests indicate no variation in tape life due to either various atmospheres or between machines. The largest variations appear to be between launch and orbital machine operation with tape pack to tape pack variation being second.

LIFE TESTS

S/N 802 Testing:

Life Test #1 - This test was set up as a pressure belt life test to be run in laboratory environment with plastic covers on the transport. The machine was operated in the launch position (reel down). The tape was run in (400 passes) 8998 tape, 3M Lot #41563-03-1-21, from Raymond reel S/N 6 purchased on Raymond Purchase Order No. 63903.

At 4980 tape passes the flutter increased from 1.0% to 1.6%. Initially the unit was thought to have a bad bearing in one of the mechanical modules. However, through cleaning of the tape path areas and retensioning of the tape pack, satisfactory operation was regained (1.2% flutter). The belt life test was re-started.

At 6700 tape passes the recorder was found to have a heavy

build-up of debris between the heads. The unit was again cleaned at this time and the belt life test continued.

At 7200 tape passes the tape pack seized. The machine was opened, visually inspected and a failure analysis performed. The following is a copy of the resulting failure report.

LIFE TEST FAILURE REPORT - Recorder S/N 802 (Failure Date 7-24-67)

A. This report discusses the recent failure of a test tape pack in OSO recorder S/N 802. This recorder is a pressure belt/tape life test being performed per NASA Contract NAS5-9395, Item 14.

a. Mechanical Configuration

The S/N 802 transport had been equipped with the new GSFC reel. A standard Raymond wrap around guide and pressure pad are used. The reel was equipped with type 3M 8998 tape from 3M lot 41563-03-1-21 purchased on Raymond Purchase Order 63903 received 11-29-66. Pressure belts of 1 mil Mylar set to tensions between 3400 - 3900 psi were used. Machine performance up to time of failure was good.

b. Operating Time

S/N 802 had operated in playback mode at room temperature for 648 hours prior to failure. This is equivalent to 7200 tape passes.

B. OBSERVATIONS

Debris had been forming at the pressure pad, input capstan and

heads. No debris was deposited directly on head gaps but was deposited on heads in area where tape approaches and leaves head. In addition the pressure belts were somewhat contaminated with debris.

The deposition of loose tape debris increased in quantity during the last week of pack life. No decrease in recorder performance was noted until time of failure.

The failure was seen to cause severe "roping" of the tape. See photos. The following conditions were noted.

1. Tape over heads was "roped" but still under pressure belts.
2. Tape still around hub was wrinkled.
3. Stress patterns about 180° each side of pack.
4. First 13 turns of tape on pack O.D. were very tight. These turns lifted upon removal of reel cover due to high stresses.
5. Six and one half turns on pack O.D. were partially folded along tape travel axis. The fold over was about 20% of each edge thus causing the "rope" appearance as seen in the photographs. The next five turns were single folded. The 13th turn indicated a return to normal 1/4" wide tape. The bulk of the tape pack had, as mentioned earlier, two stress patterns. The stress patterns were the result of local layer to layer compression of the tape. The tape had been forced towards the I.D. of the reel so that all available slack was displaced to the two areas mentioned.

There was a considerable amount of loose tape debris in the reel and on the recorder main plate in the immediate area of the tape path. Indications were that the pack seize-up was violent and caused the tape much distress.

6. The first idler to capstan belt was off the pulleys at the time the failure was discovered. The belt had been forced off as a result of the failure. Apparently the belt could not transmit the necessary torque required to further distress the tape so it gave up. The belt was not damaged.
7. Mechanical modules were checked and found to be O.K. No damage to the recorder proper had taken place.

C. CAUSE

At this time any attempt to pinpoint the exact cause for failure would be optimistic. A few theories exist and will be discussed.

1. It may have been possible for static electricity build-up to cause layers of the tape to adhere. This would prevent the normal action of interlayer slippage. A lack of free layer slip would ultimately increase the tape wear leading to an excessively loose pack or causing local layer bindup. In the event of an increase in tape slack, the danger of the tape snagging on transport protrusions or folding back into the pack becomes serious. The local layer bindup can cause compression of the pack leading to failure through sheer mechanical bind.

2. If static build-up were absent, but the tape surfaces burnished to the extent of providing very smooth surfaces, then mechanical adhesion of layers becomes a problem. If the outside layers of tape were to bind together a condition, similar to the static produced failure mode outlined above, is produced which will ultimately prevent free movement of the tape layers. Pack "blocking" then results as the overall tape tension increases to final seize up.

SUMMARY

No definite reason for the failure has been determined. The failure could have occurred as a result of the aforementioned modes. I believe more comprehensive tests could be performed to gain greater insight into failure mechanisms. We are dealing with a failure situation which is not easily reproduced time after time. Therefore, sporadic failures of this sort are extremely difficult to analyze.

It may be necessary to look for a tape better able to yield consistent results.

LIFE TEST #2

This was the first life test performed to evaluate the ability of 8998 tape to meet the mission life objectives. The test was set-up with run-in (400 passes) 8998 tape, 3M Lot #41563-03-1-21, from Raymond reel S/N 6 purchased on Raymond Purchase Order No. 63903. The recorder was in the launch position (reel down) with plastic covers. A

continuous 100% nitrogen purge was provided to insure a controlled flight atmosphere.

At 2882 tape passes the tape splice broke. This was judged to have been brought on by a sharp edge on the tape reel cover plate. The tape splice parted at the tape end interface. The sharp reel scuffing the splice edge as the splice passed by the edge plate caused the splicing tape to wear, resulting in the final failure of the tape. Examination of the tape revealed no damage whatsoever to the lubricant or oxide surfaces of the tape. The reel plate was reworked to remove the sharp edge and the test was continued after re-splicing the tape.

At 3074 tape passes during a visual check in the heads-up position, the tape pack was observed to slow and the tape start to seize. The failure was seen as rapid intermittent changes in playback frequency. The frequency shift amounted to a change in speed of greater than 50%. However, no visible evidence of tape trouble was noted. The recorder was turned to the reel up position and at that time the recorder was seen to slow down. The tape was rumpled in the area of the tape exit point of the reel.

The reel cover was removed and the tape examined. The failure was similar to the first failure except that it was caught before total destruction of the tape occurred. Approximately the first fifteen layers of tape on the pack O.D. had adhered tightly to one another. The oxide and lubricated surfaces of the recording tape were highly

polished. Evidence of inward stresses were visible as rippled tape immediately below the outside layers.

LIFE TEST #3

This test was set-up with run-in (400 passes) 8998 tape, 3M Lot No. 41563-03-1-21, from Raymond reel S/N 8, purchased on Raymond Purchase Order 63903. The recorder was in the launch (reel down) position for this test. A continuous 100% nitrogen purge was provided to insure a controlled flight atmosphere.

At 1090 tape passes the front cover of the recorder was removed and electrostatic measurements of the pressure belts and tape were made. No static charges could be found at this time. During these measurements the pressure belts were damaged and were replaced. The machine was cleaned, the test was re-started under original conditions.

At 2739 tape passes the splice broke. The failure mode was similar to the splice failure of test number 2.

At 4229 tape passes the tape pack failed. The failure mode was identical to that of test number 1.

LIFE TEST #4

This test was set-up with run-in (400 passes) 8998 tape, 3M Lot No. 41563-03-1-21 from Raymond reel S/N 6, purchased on Raymond Purchase Order 63903. The recorder was in the launch (reel down) position for this test. The unit was sealed with an atmosphere of 70% nitrogen, 20% Freon, and 10% helium pressurized to approximately 20 psia.

At 4000 tape passes the recorder operation became erratic. The flutter varied from 1.1% to 2.1%.

At 4235 tape passes the tape failed. The failure mode was different than that of the previous tests. The tape had in some way come out from under the pressure pad and free of the tape guide. The capstans both had a build-up on the tape contact areas. The belief is that the build-up on the downstream capstan was great enough to reverse the capstan differential and allow the tape to lift off of the heads. With the tape slack it could then work itself loose of the tape guide.

LIFE TEST #5

This test was set-up with run-in (400 passes) 8998 tape, 3M Lot No. 41563-03-1-21 from Raymond reel S/N 8, purchased on Raymond Purchase Order 63903. The recorder was in the orbital (heads up) position for this test. The unit was sealed with an atmosphere of 70% nitrogen, 20% Freon, and 10% helium pressurized to approximately 20 psia.

The recorder at the start of life test was a 1.0% flutter machine with a 0.48v p-p P/B analogue and 5% AM. The flutter remained at 1.0% to approximately 8000 passes at which time it started to increase, reaching 2.0% at the time of failure. The AM increased to 10% at approximately 6500 tape passes where it remained until failure. The P/B analogue output decreased gradually throughout life to 0.40v p-p at the time of failure.

Failure occurred at 10,300 tape passes. This was observed as a loss

of P/B signal and an increase in input current to a value equivalent to P/B motor stall current.

The unit was removed from test and opened for visual inspection. The failure was observed to be similar to the failure of Test No. 1-S/N 802. The debris was found not to be excessive. The available debris and tape pack was given to the NASA T.O. for analysis by NBS.

LIFE TEST #6

This test was set-up with run-in (400 passes) 8998 tape, 3M Lot No. 41843-02-1-21, from Raymond reel S/N 58 purchased on Raymond Purchase Order 66046. The recorder was in the orbital (heads up) position for this test. The unit was sealed with an atmosphere of 70% nitrogen, 20% Freon, and 10% helium pressurized to approximately 20 psia.

Recorder operation during this test was as follows:

<u>P/B Level</u>	<u>Flutter</u>	<u>AM</u>	<u>Total Passes</u>
0.65v p-p	1.8%	2.0%	5
0.48v p-p	1.2%	2.0%	1700
*0.54v p-p	1.5%	2.0%	3222
0.51v p-p	1.5%	15.0%	6966
0.53v p-p	1.5%	15.0%	12000
0.54v p-p	1.3%	15.0%	16128

*NOTE: New Recording.

The test was terminated at 16,128 tape passes by direction of the NASA T.O. and Raymond concurrence to support testing required on

the OSO "F" flight program. The unit was visually inspected and found to be extremely clean from tape debris.

S/N 801 Testing

Life Test #1 - This test was originally intended to be conducted with cured MT22760 (curing process - 200°F soak for 24 hours) run-in for 400 tape passes. However, initial evaluation of machine operation demonstrated excessive flutter (73.0%) resulted from the use of the cured tape. The MT22760 tape in its uncured state was found to operate in an acceptable manner (1.5% flutter).

The reason for attempting the use of cured tape for this test was an outgrowth of the 1964 Mariner recorder program at Raymond. At that time it was found that the MT22760 type of tape demonstrated improved stability over temperature after being cured. The operational temperature specifications of the OSO recorder are relatively low and the need for curing tape used in its life test was decided to be non-existent.

The life test was set-up with uncured MT22760 tape run-in for 400 passes and the recorder sealed with an environment of 70% nitrogen, 20% Freon, and 10% helium. The recorder was operated in continuous playback in the orbital (heads up) position.

Recorder operation during this test was as follows:

<u>P/B Level</u>	<u>Flutter</u>	<u>AM</u>	<u>Total Passes</u>
0.5v p-p	1.8%	10.0%	5
0.3v p-p	1.0%	10.0%	5000
0.28v p-p	2.2%	15.0%	8000
0.25v p-p	2.3%	15.0%	10000
0.21v p-p	2.5%	15.0%	11500
0.36v p-p	2.5%	20.0%	13500
0.36v p-p	2.5%	20.0%	13940

The test was terminated at 13,940 tape passes upon the direction of GSFC. The recorder was opened and visually inspected at the end of the test. The debris on capstans, guide, pressure belts, cover, and heads was more severe in this machine than in any other test previously observed. Debris between the heads completely filled the area and contacted the tape. The pressure belts were completely covered to the point of being totally black and opaque in appearance. The capstans were dirty but no appreciable build-up had occurred. The lower two rollers in the reel assembly showed excess and relatively uniform build-up of tar. The third roller was relatively clean. The tape, debris, and photographs have been given to the NASA T.O. for further evaluation by NBS.

LIFE TEST #2

This test was set-up with 8998 tape run-in for 400 passes. This tape was 3M Lot No. 41843-02-1-21, Raymond reel S/N 58, purchased on

Raymond Purchase Order 66046. The recorder was operated in continuous P/B mode in the orbital (heads up) position. The unit was pressurized to approximately 1-1/2 atmospheres with a gas composition of 70% nitrogen, 10% Helium and 20% Freon.

Recorder operation during this test was as follows:

<u>P/B Level</u>	<u>Flutter</u>	<u>AM</u>	<u>Total Passes</u>
0.5v p-p	1.5%	2.0%	5
0.5v p-p	2.0%	5.0%	3340
0.5v p-p	2.0%	5.0%	5270
0.5v p-p	2.0%	5.0%	10000
0.44v p-p	2.0%	5.0%	11000
0.30v p-p	2.0%	15.0%	13900

The test was terminated at 13,900 tape passes by direction of GSFC in order to facilitate evaluation of the tape problem on the OSO "F" flight program.

The transport was opened and inspected at the end of this test. The unit was found to be extremely clean from tape debris.

CONCLUSION

This study program resulted in many good changes to the OSO recorder system. Studies which began on this program later ended in pointing out system deficiencies which, while not critical to the point of serious failure possibility, could result in loss of time and delays to the program.

Much of the actual hardware effort later occurred on hardware fabrication programs. Some additional spin-off of this study program led to consideration of circuit improvements particularly the motor drive and motor drive regulator circuits. Improvements could be made in these areas and will no doubt be done on future programs.

The head problems were successfully solved on this program. No occurrences of head weeping, core shifting and other erratic changes in base characteristics have been evident since the revised head procurement policies became effective. The tape situation is not as concise since tape vendors are traditionally out of the reach of Raymond and GSFC. There is no way to prevent a tape manufacturer from changing manufacturing techniques at will. It often takes only a small change in surface chemistry to cause a recorder's performance to suffer. More work in the area of tape study is needed. It is also necessary to perform more life tests to gain the statistical background needed to reach a point of knowing the overall performance limitations of the system. Until this is done great difficulty will be had in correlating tape characteristic variation with true operational life.

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